

In-Situ Resource Utilization: Water Extraction from Regolith (ISRU)

Completed Technology Project (2017 - 2018)



Project Introduction

Several technologies are being evaluated to extract water from a variety of water-bearing extraterrestrial soils, including near-surface granular and hard hydrated soils, and subsurface ice at Mars, as well as frozen icy soils in the near permanently shadowed regions at the lunar poles. The water can be extracted from the raw resources either by transferring the raw resource into a processor, or by processing the raw resources in situ (where they are found).

One technical approach under investigation is to transfer water-containing soil to a closed processor in either a batch mode or semi-continuously, then apply energy to liberate the water. Currently, terrestrial screw conveyor soil dryers are being investigated at Johnson Space Center (JSC) for their adaptability to use in lunar or Mars conditions. At the same time, NASA Jet Propulsion Laboratory (JPL) is investigating the use of microwave energy to liberate water from soil as it flows through a processor.

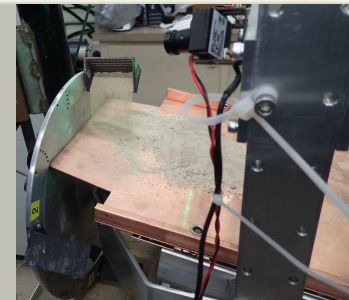
A second technical approach under investigation is to deposit water-containing soil onto a heated surface and use the Mars atmosphere as a sweep gas to collect any water vapor released in an 'open-air' continuous process. NASA Glenn Research Center (GRC) is investigating this approach to continually harvest water as the rover/excavator roams the surface. While this process may lose some of the evolved water, it eliminates the need for reusable, high-temperature, dusty seals, and provides heat at the granular level to reduce long heating times.

A third technical approach under investigation is to extract the water directly from the raw resource without any excavation of the soil. NASA Johnson Space Center (JSC) is evaluating the terrestrial Rodriguez Well approach used in Antarctica for potential use on Mars to access nearly-pure ice deposits at some depth below the surface. This approach first requires a hole to be drilled through any overburden and into the ice sheet. Heat is then applied directly to the ice sheet to melt the ice into a liquid which could then be pumped out when needed. An evaluation is underway as to the viability of the approach at Mars environmental conditions.

Water Extraction from Regolith is part of the AES In-Situ Resource Utilization (ISRU) Technology Project which is developing the component, subsystem, and system technology to enable production of mission consumables from regolith and atmospheric resources at a variety of destinations for future human exploration missions.

The overall goals of the ISRU Technology project are to achieve system-level TRL 6 to support future flight demonstration missions and provide exploration architecture teams with validated, high-fidelity answers for mass, power, and volume of ISRU systems.

The project's initial focus is on critical technology gap closure and component



Concept for 'open air' water extraction soil processor.

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development in a relevant environment (TRL 5) for Resource Acquisition (excavation, drilling, atmosphere collection, and preparation/beneficiation before processing) and Resource Processing & Consumable Production (extraction and processing of resources into products with immediate use as propellants, life support gases, fuel cell reactants, and feedstock for construction and manufacturing). The interim project goal is to complete ISRU subsystem tests in a relevant environment to advance the subsystem to TRL 6. The project end goals are to perform end-to-end ISRU system tests in a relevant environment (system TRL 6) and integrated ISRU-exploration elements demonstrations in a relevant environment.

ISRU is a disruptive capability that enables more affordable exploration than today's paradigm where all supplies are brought from Earth, and allows more sustainable architectures to be developed. The availability of ISRU technologies can radically change the mission architecture and be the sizing design driver for other complex systems already in development. For example, the current Mars architecture assumes ISRU production of up to 30 metric tons of propellant on the Mars surface in order to reduce the ascent vehicle landed mass by 75 percent and reduce Earth launch needs by at least 300 metric tons. If a decision was made to use storable propellants for the Mars ascent vehicle instead of ISRU-producible oxygen and methane, many other drastic changes to the architecture could be required, such as lander and ascent vehicle size, number of landers needed, surface operations for ascent vehicle fueling, and Mars rendezvous orbit. Other surface systems might become more complex or heavier if they are not designed to take full advantage of ISRU technologies. Examples include a more complex closed-loop life support system if resupply with ISRU water cannot be assumed, or a heavy, built-in habitat radiation shield if a water- or regolith-based shield cannot be added after habitat delivery to the surface.

Other system designers may also make decisions that reduce the benefit of incorporating ISRU into the mission, resulting in a larger or more inefficient ISRU system. For example, a non-continuous power source such as solar power would increase the required production rate and peak power of an ISRU plant, thus increasing its size and complexity due to hundreds of start-stop cycles. However, a continuous power source, such as nuclear or solar power with storage, would allow an ISRU plant to operate continuously, thus minimizing its size, complexity, and power draw. These are only a few examples of how the inclusion of ISRU has ripple effects across many other exploration elements.

ISRU is also a new capability that has never before been demonstrated in space or on another extraterrestrial body. Every other exploration system or element, such as power, propulsion, habitats, landers, life support, rovers, etc., have some form of flight heritage, although almost all still need technology development to achieve the objectives of future missions. This is

Organizational Responsibility

Responsible Mission Directorate:

Exploration Systems Development Mission Directorate (ESDMD)

Lead Center / Facility:

Glenn Research Center (GRC)

Responsible Program:

Exploration Capabilities

Project Management

Program Director:

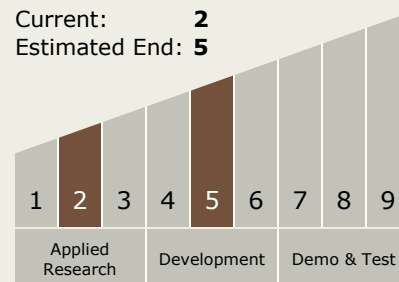
Christopher L Moore

Project Managers:

Diane L Linne
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Technology Maturity (TRL)

Start: 2
Current: 2
Estimated End: 5



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another critical reason why ISRU technology development, leading to a flight demonstration mission, needs to be started now, so that flight demonstration results can be obtained early enough to ensure that lessons learned can be incorporated into the final design.

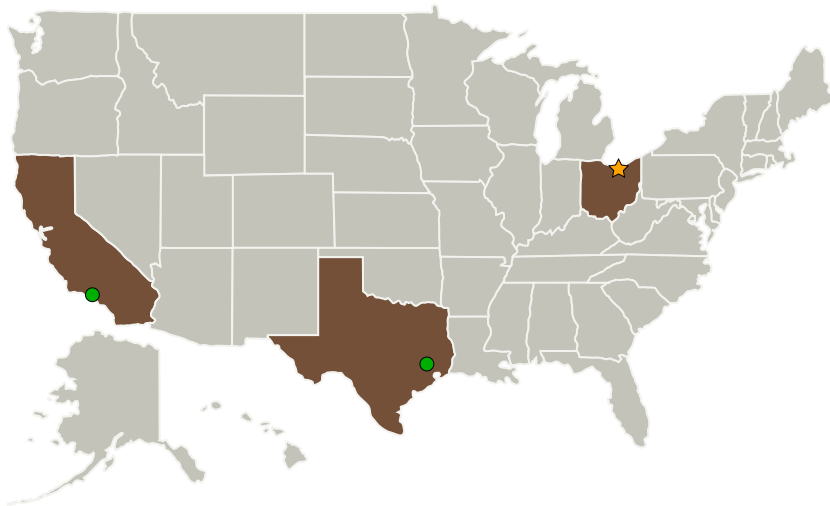
This technology development activity was transferred to the STMD Game Changing Development Program in October 2018.

Anticipated Benefits

This technology is categorized as a prototype hardware system for manned spaceflight.

Water extracted from extraterrestrial soil and subsurface ice can be electrolyzed to produce oxygen and hydrogen. The oxygen can be used for life support and propellant oxidizer, and the hydrogen can be combined with carbon dioxide from the Mars atmosphere to produce methane fuel. Producing these resources in-situ from soil- or ice-derived water can significantly reduce mission launch mass, lander size and/or number needed, reduce ascent vehicle size and/or increase rendezvous orbit, and enable or enhance mission capabilities.

Primary U.S. Work Locations and Key Partners



Technology Areas

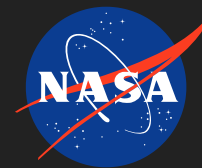
Primary:

- TX07 Exploration Destination Systems
 - └ TX07.1 In-Situ Resource Utilization
 - └ TX07.1.2 Resource Acquisition, Isolation, and Preparation

Target Destinations

The Moon, Mars, Others Inside the Solar System

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Organizations Performing Work	Role	Type	Location
★ Glenn Research Center(GRC)	Lead Organization	NASA Center	Cleveland, Ohio
● Jet Propulsion Laboratory(JPL)	Supporting Organization	NASA Center	Pasadena, California
● Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas

Primary U.S. Work Locations

California	Ohio
Texas	

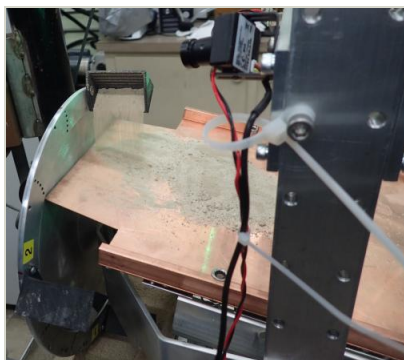
Project Transitions

▶ **October 2017:** Project Start

✓ **September 2018:** Closed out

Closeout Summary: This AES project was transferred to the NASA Space Technology Mission Directorate (STMD) as of October 2020.

Images



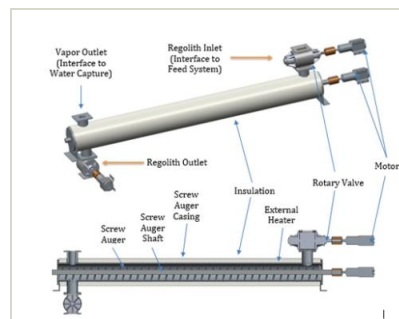
Concept for 'Open Air' Water Extraction

Concept for 'open air' water extraction soil processor.
(<https://techport.nasa.gov/image/40894>)



Microwave Water Extraction Processor

Image of microwave water extraction processor.
(<https://techport.nasa.gov/image/40895>)



Screw-Conveyor Dryer Soil Processor

Drawing of screw-conveyor dryer soil processor concept.
(<https://techport.nasa.gov/image/40893>)